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Can Functional Eccentric Muscle Control Remedies Balance Ability in Children with Spastic Diplegic Cerebral Palsy

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Abstract

Background: Eccentric training redresses the consequences of spastic muscle shortening by altering the length–tension characteristics of muscle to operate at longer lengths

Purpose: Purpose of this study was to study the effect of eccentric control training on balance and gross motor function in children with Spastic Cerebral Palsy.

Methods: The study was prospective controlled study, simple randomization plane used to assign participants, triple blind study (participant, outcomes assessor, data analysts). 40 children with spastic cerebral palsy were enrolled from the pediatrics' out-patient clinic, faculty of physical therapy, Cairo University.

Participants randomly divided into experimental and control groups. The experimental group received 60 minute of neurodevelopmental technique and eccentric control exercise. While, 60 minute of neurodevelopmental technique was applied for the control group. Stability index of The Biodex balance system (primary measure) as well as standing and gait parameters of the gross motor function measures (secondary measure) were evaluated before and after the trail.

Results: There was a significant difference between the control and the study group in the overall stability indices in favour of the study group (P<0.001) with confidence interval 95%. Significant increase in the values of GMFM post treatment of study group compared with the control group (p<0.02).

Conclusion: Eccentric control exercise therapy in children with spastic Cerebral Palsy is an effective approach to develop balance and gross motor function.

Keywords: Spastic cerebral palsy; Eccentric control training; Gross motor function; Balance

Introduction

Cerebral palsy (CP) is a neurodevelopmental disorder and is the major cause of motor disability in children that affect the immature brain [1]. More than 70% of CP cases are classified as having spastic cerebral palsy. Involvement of the upper extremities is less than the lower extremities in Diparetic cerebral palsy (DCP) [2]. The Gross Motor Function Classification System (GMFCS) organizes children with CP into five groups according to their gross motor abilities [3].

Additionally, The Gross Motor Function Measure (GMFM) is a criterion-based observational measure evaluate change in gross motor function in children with cerebral palsy, the GMFM-88 exhibit high completion rates that confirmed the relevance of the outcome measures to the functional ability of children with cerebral palsy [4,5]. Eccentric muscular contractions occur when the load force is greater than the resisting muscle force, and as a result the active muscle is lengthened [6]. Eccentric training leads to increase muscle efficiency through changing the torque–angle relationship of the longer length muscle owing to increased sarcomeres numbers (in series) [7]. Muscles produce greater force more easily eccentrically than concentrically [8].

Eccentric training arrange for neurological benefit for children with motor control deficiency, as it decreased the demand on the upper motor-neuron system [9]. Eccentric training for the paretic leg in patients with hemiplegia conveyed improvement of muscle strength, velocity, cadence, and weight-bearing on the paretic side during walking [10]. Biodex Stability System (BSS) was used for evaluation of dynamic balance. This system consists of a movable balance platform, which provides unstable surface tilt up to 20-360 range. It evaluates the ability of remaining stable on the unstable platform so it assesses neuromuscular performance.

The data obtained from motion of the unstable platform represented as the deviations from the horizontal plane (Overall stability index "OSI", Anterior/Posterior stability index "AP", Medial/Lateral stability index "ML"). The BBS platform has eight stability levels ranged from a completely firm surface (stability level 8) to a very unstable surface (stability level 1) [11,12].

The aims of this research are to determine the effect of eccentric controlled movement training on balance ability and gross motor function in children with spastic cerebral palsy.

So this Research hypothesized that functional eccentric control training has no effect on balance and gross motor function in Children with Spastic Cerebral Palsy.

Subjects and Methods

Study participants

About 40 children with spastic cerebral palsy were divided into two groups (experimental and control groups). The inclusion criteria were as follows: children with spastic cerebral palsy with mild spasticity (grade 1 to +1) by modified ashworth scale., Gross Motor Function Classification System (GMFCS) level I–II and capable of standing and walking, absence of vision or hearing deficits, and no medicine or surgery that affects balance, their age ranged from 7 to 9 years old, Their heights were more than 100 cm and their weights were more than 20 kg (as those are the minimal requirement of height and weight needed by biodex stability system) [13].

Parents sign up consent form to participate in the study; they were divided randomly by simple randomization plane (online software). Ethical approval from the human research ethics committee of faculty of physical therapy, Cairo University was received for this study, triple blind study (participant, outcomes assessor, data analysts). This study is an A-B-A design in which evaluation was conducted before and after 3 months of successive treatment. The study started on 3rd of January 2017 and post treatment measurement was conducted at 3rd of April 2017 3 sessions per week.

Instrumentation

The Biodex stability system: Evaluation using balance using Biodex stability system was done for each child. The BBS (Biodex Crop. Shirley, NY) is a unique dynamic postural control assessment and training system. The Biodex stability system consists of the following:

Support rails: Adjustable from 25" to 36.5" above platform. The rails could be swing away from platform if desired.

Platform: Its height is 8" above floor, with a diameter of 21.5". The platform could be tilted up to 20 degrees from horizontal in all directions. The Biodex stability system had 8 stability levels. These levels indicate the stiffness of the platform. Stability level 8 indicates a most stable platform surface, whereas stability level 1 indicates a very unstable surface.

Display: Its height could be adjusted from 51" to 68" above the platform. Display Angle: Adjustable from vertical back up to 45 degrees. Display viewing Area: 122 mm × 92 mm. Display Accuracy: ± 1 degree of tilt.

Printer: Cannon Bubble-jet printer, 80 column, centroids parallel interface.

Each child in both groups was evaluated by the dynamic balance test. The parameters should supply to the device were:

- Child's weight, height, and age.
- Platform firmness (stability level): All children were tested on two stability levels; stability level 8 (most stable platform) and stability level 1 (the least stable platform) for 3 times repetitions for each level of stability.
- Test duration: All children were tested for 30 seconds.

Child centering step: To position the center of gravity (COG) over the point of the vertical group reaction force.

- The child to stand on both feet while grasping the handrails.
- The child was then instructed to achieve a centered position on a slightly unstable platform by shifting his feet position until it was easy to keep the cursor (which represents the center of the platform) centered on the screen grid while standing in a comfortable, upright position.
- Once the cursor was in the center of the display target, instruction was given to the child to maintain his feet position till stabilizing the platform.
- Recording feet angles and heels coordinate from the platform.
- Then the test began. As the platform advanced to an unstable state, the child was instructed to focus on the visually feedback screen directly in front of him without grasping hand rails and attempt to maintain the cursor in the middle of the bulls eye on the screen.
- A report included information of overall stability index, mediolateral stability index, and anteroposterior stability index.
- The mean values of three trials, of stability indices were calculated for each child.

The gross motor functional measures

The GMFM measures the change in motor function in children [14,15]. The children were asked to perform 88 kinds of activities in 5 domains without help. Among the 5 domains, total scores in domain D (standing) and domain E (gait, running, and jumping) used in this study.

- The items are scored from (zero-three). Values of 0=cannot do; 1=initiates (<10% of the task); 2=partially completes (10<100% of the task); 3=task completion.
- Total score of total points for dimension D and E of were assessed then a percent score was calculated this dimensions.
- A percent score=(child score/maximum score) × 100%
- All tasks of the GMFM-88 were administered in Pediatric Physical Therapy room that was comfortable and familiar to the children.
- The tasks were done in the same order given in the GMFM manual. During the tasks.
- Assessment was done barefoot and with no assistive devices.
- Time required recording each child score was 20 to 30 minutes.

Eccentric control exercise intervention

A group of selected functional tasks was conducted for the study group that meets the recommendations of international classification of function ICF-CY as follow:

Eccentric control muscle contraction exercise was conducted from standing and return to sitting on chair slowly to activate eccentric muscle contraction of gluteus maximus and anterior tibial group,

- Standing and shift weight anterior slowly (activating first heel rocker and second ankle rocker).
- Sitting and return to crock lying gradually.
- Standing single limb support and kick large ball backward slowly to specific target on a mirror placed behind child.
- Each exercise was done for 5 times and repeated for 10 set with rest in between sets.

Neurodevelopmental technique (both groups)

- Select appropriate key/s of control.
- Facilitation of normal movement pattern in functional tasks.
- Promote postural control during standing and walking domains.
- Enhance open and closed chain activities.

Data were fed to the computer and analyzed using SPSS software package version 20.0. Tested for normality using Kolmogorov-Smirnov test, Shapiro-Wilk test and D'Agstino test was conducted. Parametric tests were applied, if it reveals normal data distribution. In case of abnormally distributed data non-parametric tests were used.

Comparison between two independent populations was done using independent t-test; as well paired t-test is used to analyze two paired data for normally distributed data.

Comparison between two independent populations were done using Mann Whitney test for abnormally distributed data. Significance of the obtained results was judged at the 5% level confidence interval 95% value ≤ 0.05 was considered significant.

Results

The collected data from this study represent the statistical analysis of the stability indices SIs (overall SI, anteroposterior SI, mediolateral SI) of the dynamic balance test, at two level of stability; level 8 (more stable platform) and level 1 (least stable platform) The result obtained from both, study group (B) and control group (A) was calculated and compared before and after the trail.

The Biodex balance system measure: Statistical analysis of the mean values of overall stability index post treatment for the study and control group showed significant differences. The improvements percentage was 10.1% in favor of the study group (Table 1).

Stability Index (SI)		x̄+SD	P Value	Sig
Overall SI				
Control group	Pre	1.5917+0.45	<0.001	s
	Post	1.4642+0.36		
Study group	Pre	1.6+0.39	<0.001	s
	Post	1.3+0.21		

x̄: Mean; MD: Mean Difference; p value: Probability value;
SD: Standard Deviation; t value: Unpaired t value; S: Significant

Table 1: Comparison of the mean values of the stability indices pre and post treatment for the study group and the control group.

The gross motor function measures (GMFM): Data obtained from both groups prior and following the treatment program regarding GMFM were statistically analyzed and compared I. Pretreatment median values of GMFM of the two patient groups (study and control): were 55 and 58 respectively, recording no significant difference in the median values of GMFM pretreatment between study and control groups (p=0.64) (Table 2).

Post treatment median values of GMFM of the study and control groups revealed that the study group was 67 and that of control group was 63.5. Significant increase in the median values of GMFM post treatment of study group compared with the control group (p=0.02) using Mann-Whitney U test.

Parameters	GMFM	MD	t- value	p-value	Sig
	x̄ ± SD				
Control group	60.25 ± 17.16	-15.75	-2.61	0.01	S
Study group	76 ± 12.8				

x̄: Mean; MD: Mean Difference; p value: Probability value;
SD: Standard Deviation; t value: Unpaired t value; S: Significant

Table 2: Post treatment mean values of GMFM between the control and study groups.

Discussion

This research was conducted to providing clinical evidence whether an eccentric training program affect Balance Ability and gross motor function in children with spastic diplegic cerebral palsy. The results showed positive effect

The present study comes in agreement with Elder et al., who demonstrated that children with CP muscle strength nearly half the strength ability of their typically developed peers [14].

Siobhn et al. highlighted that children with CP showed higher electromyography (EMG) activity across the concentric tasks in comparison with eccentric ones, predominantly in the correlation between the angles at peak torque (80-100). After the specific strengthen training program a regular trend appears where EMG activation reduced significantly for those children with CP in the eccentric effort, possibly explanation is increased specificity of neural recruitment pattern after eccentric tasks.

In general, these reductions lead to activation scores more similarly representing those of the typically developing peers. They justified the decreased EMG activation to reach normal levels by the basic physiological base declaring that eccentric muscle actions require less active neural control than do concentric actions [15].

A reduced muscle function found in those children could diminished movement and hence disrupt postural reaction efficiency, therapy changes in musculoskeletal alignment and joint biomechanics could decrease the child's ability to exhibit appropriate protective reaction, decreased range of motion, limits mobility and decreases the base of support.

This comes in agreement with Literature reviews which showed that the limited capacity to develop force is a great limitation, even more generating more limitation to the ability to move than the resistance to passive stretch (spacticity) (Ross et al. and Scholtes et al.). The weakness of the hip abductors and extensors muscles as well as the knee extensors lead to reduced hip and knee joint movement in the sagittal plane restricting the patient's gait Berry et al. [16-18].

The results of the study disagree with Taylor results of using progressive resistive training on eight children with spastic diplegia, submitted to a two and half months,. In his study he showed significant improvement in gait kinematic parameters in those children. However, neither of the active participants changed the respective functional capacity classification [19].

Specifying the study to only eccentric training is in agreement with Gage explanation of the gait of children with cerebral palsy. The study includes a gait training to deal with the decreased endurance or functional capacity of cerebral palsy children with pathologic gait. It recommends several physiologic and biomechanical explanations of normal gait that can be used to enhance energy conservation [20].

Gage et al. reported that eccentric muscle contraction as gastrocnemius function to return of stretch energy from pre-stretched muscles immediately prior to concentric contraction, also it is a bi-articulate muscles functioning as energy transfer straps, and provide joint passive stability from the effects of ground reaction forces whenever possible to spare muscle activation [21]

Measurement of effect of eccentric control training on improvement of gait came in agreement with the results of Eagleton et al. and Blundell et al. who reported that that the increase in muscle strength resulted in improvement in gait pattern with less crouch, faster speed and improved gross motor ability (standing, sit-to-stand, walking, running, jumping activities) [22,23].

On the other hand, this evidence come against the conclusion of Scianni et al. and Mockford et al. who performed a recent meta-analysis of published studies on the effect of strength training in children with CP that stated" muscle strengthening is not effective in children and adolescents with cerebral palsy" this result could be criticized by the effect size of the intervention. Though, more research is needed to help direct clinical practice and also specific protocol of strength regime to improve the gait, but to date this analysis has not been done [24,25]. And this add to the need for this study

Choosing specific set of exercise came in agreement with the assumption of Verschuren et al. who calculated Inter-tester reliability of 30 second repetitions of (lateral step-ups, sit-to-stand, and standing from half kneeling)is acceptable, with intraclass correlation coefficient (ICC) values ranging from 0.91 to 0.96 in children with CP from seven to 17 years old [26].

Gage et al. examined Children with spastic diplegia and demonstrated that strength values ranging from 16% to 71% of same-age children depending on the muscle tested. The gluteus maximus and soleus muscles showed the greatest strength deficits. The involved side of children with hemiplegia exhibited values from 22% to 79% of strength values of same-age peers. The gluteus maximus and the anterior tibialis were the weakest muscles [21].

This study in accordance with the interpretation of Perry, who emphasized that strong eccentric contraction of the calf musculature to control the tibia essential for functional requirement of single limb support task and subsequently the rest of the stance limb as supported leg moves over the fixed base of support provided by the foot [27].

During forward sway, by imposing a stretch on the hyperactive gastrocnemius, the first muscles to respond were the hamstrings. The gastrocnemius muscle was slow to become active. The delayed activation of a stretched “spastic” muscle is consistent with the findings of other researcher, who have reported an inability to recruit and regulate the firing frequency of motor neurons in people with spastic hypertonia. Abnormal sequencing of muscle activity significantly decrease torque. In addition, this pattern of muscle activity resulted in large lateral shifts of the body’s center of mass, shown as the large oscillatory shifts in the weight record, the rational of the our study possibly explanation is that The gastrocnemius muscle should be trained in eccentric activation way to avoid abnormal sequencing of muscle activity [28].

As a final point, the systematic review of randomized trials assessed strength interventions for children with CP, strength training was found not to be clinically effective in increasing scores on the Gross Motor Function Measure [29]. What is clearly visible is much systematic review based on investigation of strength using concentric or isometric maximal voluntary exertion only in children with CP [30], and they use open-chained progressive exercises as intervention [29-32]. Which contradict the idea of following the ICF-CY model of practice? In addition to activities require complex postural control and many lower-extremity muscles to work in isometric or eccentric activity in close-chained movements, and walking also requires optimal use of skeletal lever arms and transfer of energy from one body segment to another [33] strengthening in open-chained movements or even close-chained “exercises” may not be sufficient to change walking efficiency and activity. And this may justify the important and novelty of our study as we used activated eccentric muscle activity in functional tasks either open or closed chain.

Conclusion

From the obtained results of this study, it may be concluded that, eccentric control training during functional activity that improve child level of activity and participation improved both balance abilities and gross motor function in children with Spastic Diplegic Cerebral Palsy. And this study recommends this procedure in conducting pediatrics rehabilitation protocols.

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